BM

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 4 : G01D 5/26, G02F 1/01 G02B 6/26

A1

(11) International Publication Number: WO 87/ 03676

(43) International Publication Date: 18 June 1987 (18.06.87)

(21) International Application Number: PCT/GB86/00738

(22) International Filing Date: 4 December 1986 (04.12.86)

(31) Priority Application Numbers: 8529862 8529863

(32) Priority Dates: 4 December 1985 (04.12.85) 4 December 1985 (04.12.85)

(33) Priority Country: GB

(71) Applicant *(for all designated States except US)*: THE GENERAL ELECTRIC COMPANY, P.L.C. [GB/GB]; 1 Stanhope Gate, London W1A 1EH (GB).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)* : GEORGIOU, George, Antony [GB/GB]; 45 Oakwood Avenue, South Gate, London N14 (GB). BOUCOUVALAS, Anthony, Christos [GB/GB]; 59 Sherwood Road, South Harrow, Middlesex HA2 8AW (GB).

(74) Agent: KIRBY, Harold, Victor, Albert; The General Electric Company, p.l.c., Central Patent Department, Wembley Office, Hirst Research Centre, East Lane, Wembley, Middlesex HA9 7PP (GB).

(81) Designated States: AT (European patent), BE (European patent), CH (European patent), DE (European patent), FR (European patent), GB (European patent), IT (European patent), JP, LU (European patent), NL (European patent), SE (European patent), US.

Published
With international search report.

(54) Title: FIBRE OPTIC DEVICES

(57) Abstract

A fibre optic device which can be used as an attenuator or a sensor. The fiber has a biconical taper which can be immersed in a medium having a higher refractive index so that light transmission through the fibre can be used as a sensor in measuring temperature, refractive index. When used as a tuneable attenuator electrodes are mounted in contact with the medium so that it can be heated to vary transmissivity through the fibre.

Fibre Optic Devices

The present invention concerns optical fibre devices. It has been discovered that optical fibre couplers can be fabricated by imparting a biconical taper to a monomode optical fibre. With the aid of such tapering the core HE_{11} mode can couple into the HE_{11} mode of the tube waveguide, which is formed due to the cladding, in an efficient manner.

The present invention has for an object to utilise optical fibres having such biconical tapers to form devices, including sensing devices and tuneable attenuators, which are simple to manufacture and which incorporate low cost electronics.

Accordingly from one aspect the present invention consists in an optical fibre device comprising a monomode optical fibre having an optical coupler fabricated therein in the form of a biconical tapered portion, means for modifying the refractive index of a medium surrounding the tapered portion so that for a specified wavelength travelling along the fibre the power transmitted will vary in accordance with variation in the refractive index of the medium, and means for detecting light transmitted by the core of the optical fibre.

In order that the present invention may be more readily understood, two embodiments of devices constructed in accordance with the invention will now be described

into the tapered section. The tapering being applied causes the tapered portion to become a multi-mode section, and interference of the local HE_{11} and HE_{12} modes causes power transfer along the taper. If the taper length is such that for the particular taper shape power emerges at the taper end in the core of the fibre, then the light will be transmitted. If, however, it emerges in the cladding it will be lost. This can be seen from the plot shown in Figure 2 which consists of power oscillations induced by the tapering process. Figure 2 shows the result if the taper is elongated until it breaks. However, the tapering process can be stopped at will. Figure 3 shows the power transmission response when extension of a fibre portion to produce a biconical taper has been stopped just after 1½ detected power oscillations.

A tapered optical coupler produced by this procedure can be incorporated in a range of sensing devices by utilising the refractive index response of the tapers. Then if the tapered portion is immersed in a liquid such as silicone oil, which has a higher refractive index than silica, and the liquid is heated so that its refractive index varies the response of the taper to light of a particular wavelength will vary. This variation is shown in the plot of Figure 4.

From this plot it can be seen that there is maximum power transmission at point A. This is at a temperature of 29°C. At higher temperatures the power throughput decreases almost linearly as temperature rises. Thus point B shows power transmission at 55°C. The section A-B of the plot can be used to provide a sensor with relatively low sensitivity and good dynamic range in which a change of refractive index of the order of 10^{-2} corresponds to a change in temperature of approximately 30°C, and requiring a detection sensitivity range of ~20 dB. These figures provide the basis for an intensity sensor for the measurement of temperature, refractive index, acoustic, biological and other sensors

The outputs of the detectors are connected to logarithmic amplifiers 16, 17 the outputs of which are divided by a divider 18. The result is a linear output as a function of temperature, or of refractive index of the substance surrounding the biconical taper. Thus temperature, refractive index and acoustic sensors can be made with this arrangement.

Such sensors would be simple to make with low cost electronics.

Another application involving this relationship, and in particular part A-B of the refractive index response is that of a tuneable attenuator. By changing the refractive index surrounding the taper the throughput attenuation is changed linearly in dB. Thus Figure 5 shows a tuneable attenuator. A monomode optical fibre 1 has a biconical taper fabricated in it in the region generally indicated at 2. This region is housed in a capillary glass tube 3 filled with a liquid such as silicone oil the refractive index of which varies with temperature over the required ranges. The ends of capillary 3 are sealed with UV-cured epoxy resin. The tube is coated with resistive material and provided with electrodes 4 and 5. The application of a voltage across the electrodes causes the heat released to heat the liquid and lower its refractive index, hence varying the transmission through the fibre 1. In this manner a tuneability of >30 dB can be achieved.

grow single KDP crystals long enough to clad the taper region and also to enclose the modulating electrodes.

As an alternative, low refractive index liquid crystals are used with SiO_2 guides or with high refractive index glass fibre tapers.

For modulators of the kind just described the necessary change of refractive index of the surrounding medium is $< 10^{-3}$.

Such a modulator would find ready application in digital transmission systems. The actual structure of a modulator employing the principles just discussed is similar to that shown in Figure 5 of the drawings.

Fig.1.

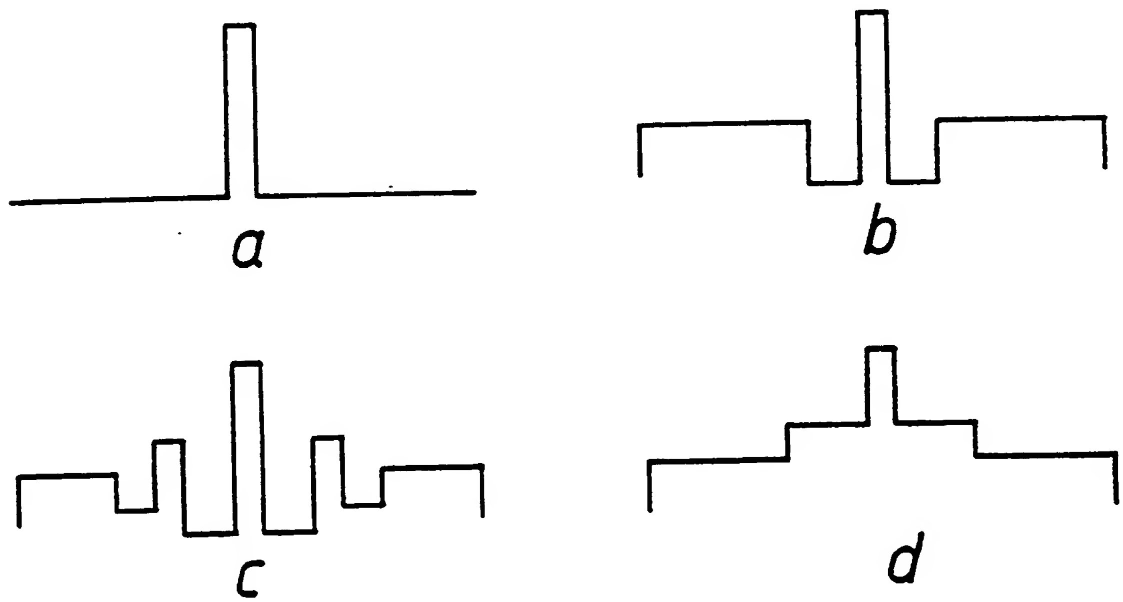


Fig.3.

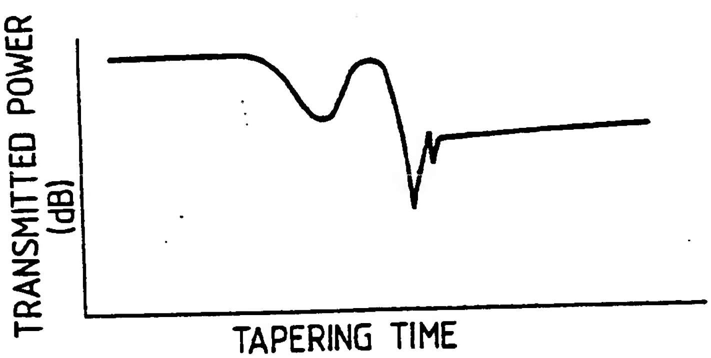


Fig.6.

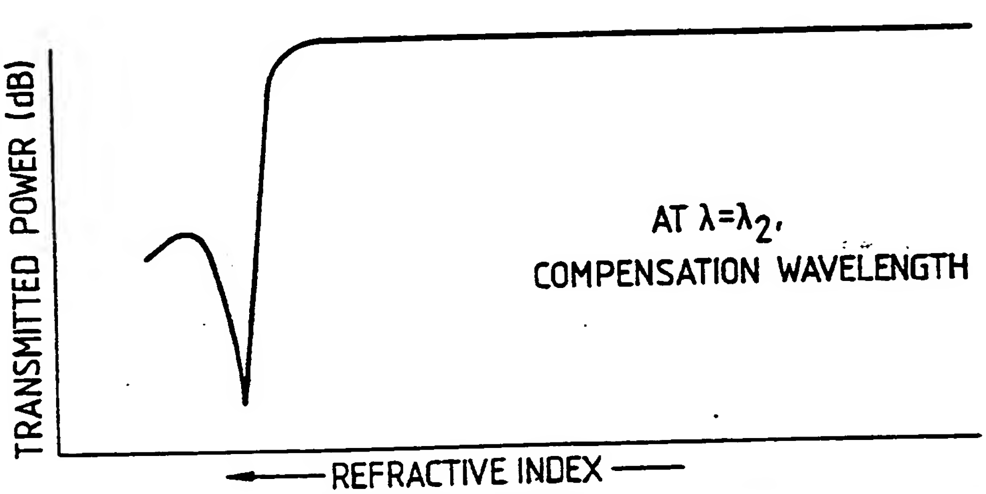


Fig.5.

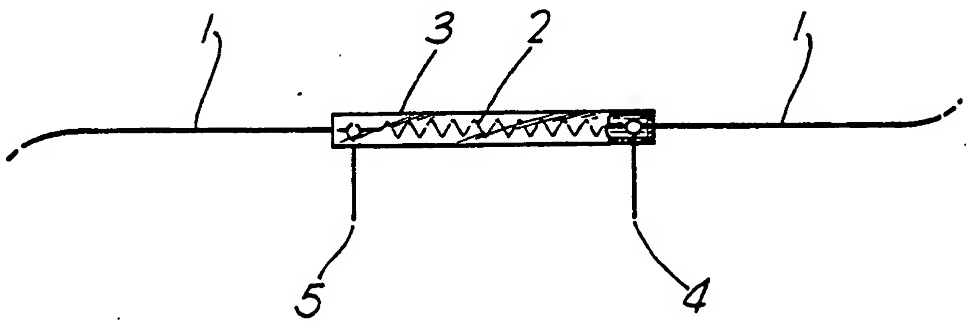

1
3
2
1
5
4

Fig.7.

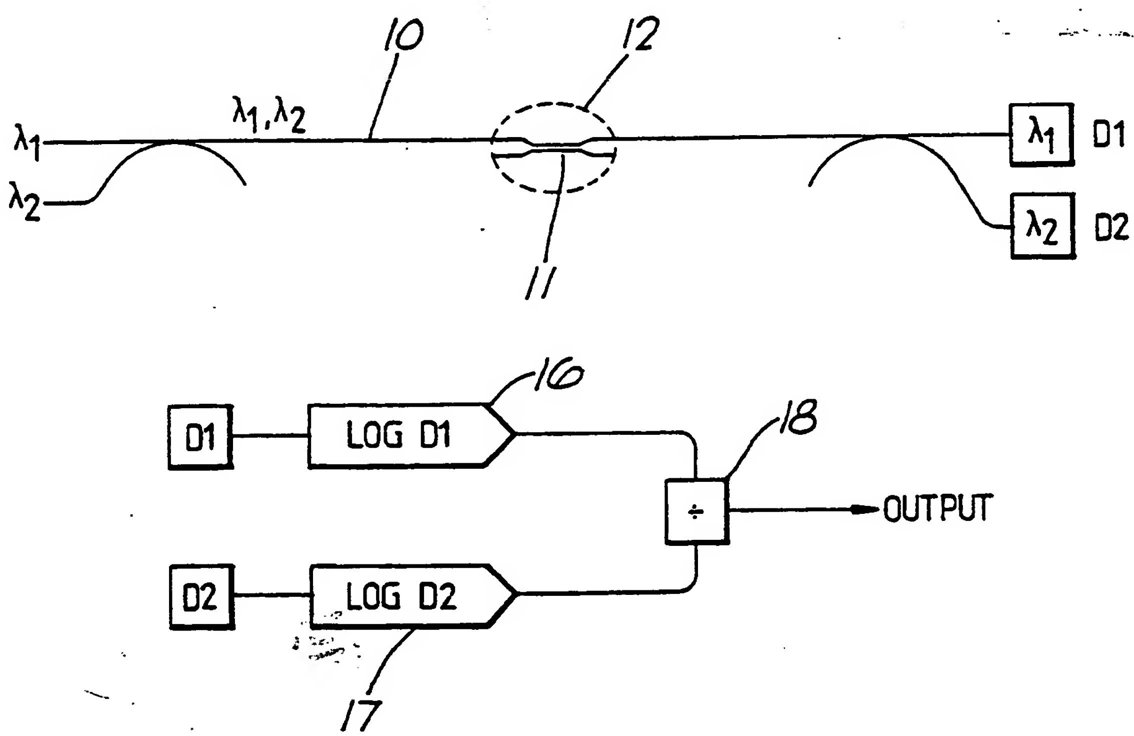

10
12
λ_1, λ_2
λ_1
λ_2
λ_1
D1
λ_2
D2
11
16
18
D1
LOG D1
÷
OUTPUT
D2
LOG D2
17

Fig. 10.

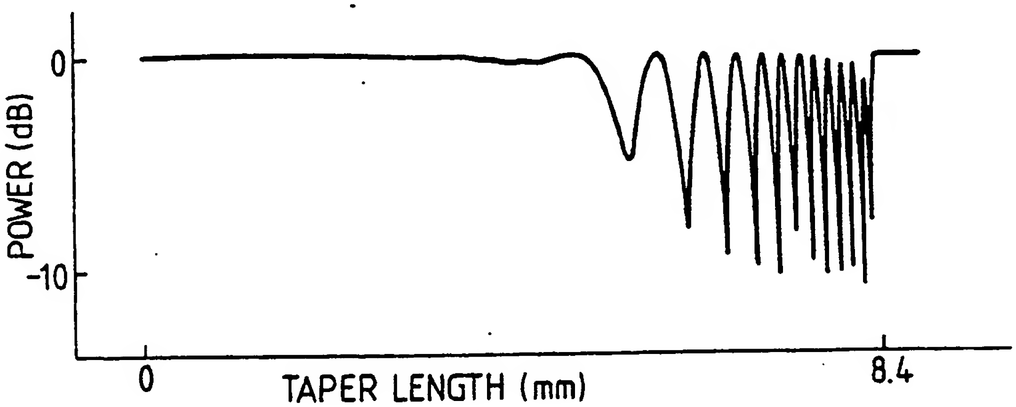
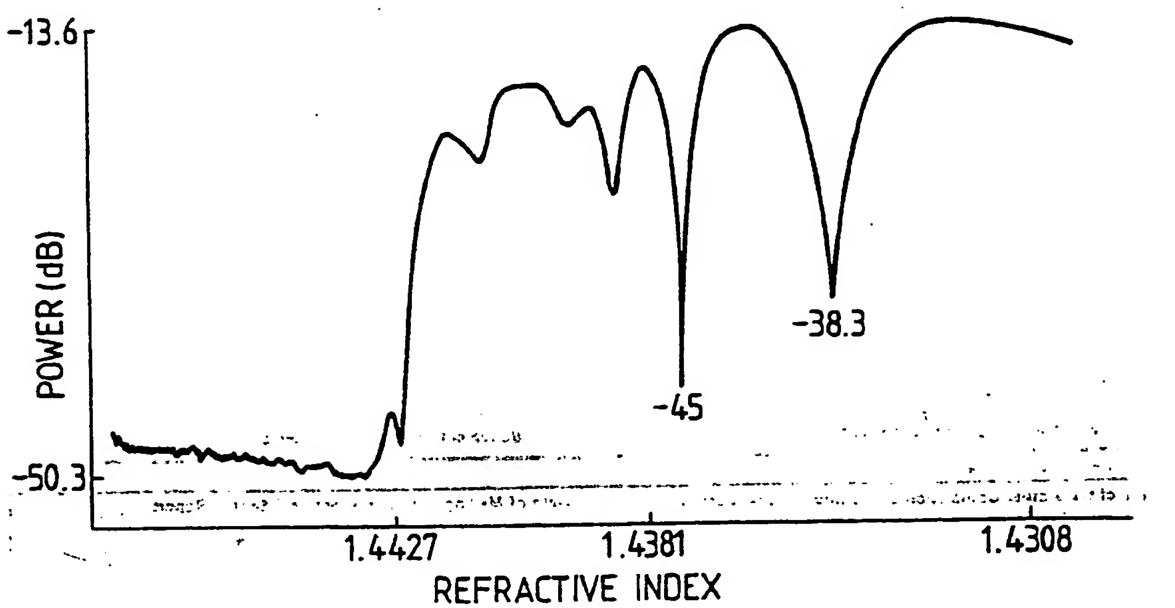

0
-10
POWER (dB)
0
8.4
TAPER LENGTH (mm)

Fig. 11.


-13.6
-50.3
POWER (dB)
-45
-38.3
1.4427
1.4381
1.4308
REFRACTIVE INDEX

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	Journal of Physics E Scientific Instruments, no. 12, December 1984, The Institute of Physics, (London, GB), B.E. Jones et al.: "Optical fiber sensors using wavelength modulation and simplified spectral analysis", pages 1240-1241, see figure 1; page 1240, column 2, lines 1-18	1,2
	--	
A	Electronics Letters, volume 18, no. 3, 4 February 1982, Institution of Electrical Engineers, (Hitchin, Herts, GB), J.R. Cozens et al.: "Coaxial optical coupler", pages 138-140, see the whole document	1,4
